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BRITISH MUSEUM (NATURAL HISTORY)

THE

JOHN MURRAY EXPEDITION
1933–34

SCIENTIFIC REPORTS

VOLUME V, No. 2

PTEROPODA

BY

H. G. STUBBINGS, M.A.(CANTAB.), B.SC.(LOND.)

(Late Scholar of St. Catharine's College, Cambridge)

WITH TWO TEXT-FIGURES

LONDON:
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AND AT

THE BRITISH MUSEUM (NATURAL HISTORY), CROMWELL ROAD, LONDON, S.W.7

1938

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Price One Shilling and Sixpence

[Issued 26th March, 1938]

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INTRODUCTION.

THE small collection of Pteropoda contains eighteen species of Thecosomata and two of Gymnosomata, the latter each occurring once only. This is somewhat remarkable, as Meisenheimer (1905, pp. 49 *et seq.*) records the following genera and species of Gymnosomata as having been taken in the area : *Pneumoderma peroni*, *Pn. mediterraneum*, *Thliptodon* sp., *Halopsyche gaudichaudi*, *Notobranchea* sp., and *Clionopsis* sp. The records for these species, however, are not numerous and no examples were taken by the Percy Sladen Expedition, so it is probable that the Gymnosomata are only poorly represented numerically in the Arabian Sea.

The majority of the species included in this report are represented by specimens from only a few localities ; nevertheless there are sufficient records to show that many of the species are widely distributed in the Arabian Sea. The presence of Pteropod shells widely distributed on the sea-floor strengthens this belief. Hitherto records of Pteropods in the Arabian Sea have been confined to the Maldive and Chagos Archipelagos, and the course of the " Valdivia " from the Chagos Archipelago to Zanzibar and up the Somali coast to the Gulf of Aden.

Specimens were taken at 16 stations, of which only 4 yielded any number of species, namely, Sta. 131, 12 species ; Sta. 61 (night), 12 species ; Sta. 96, 8, and Sta. 172, 7 species. It may be remarked that specimens are more abundant from the " high-seas " stations than from the Maldives (only 3 species from 3 stations) and the Red Sea (a species of *Cymbulia* and doubtful remains of a second).

The most widely spread species appear from the records to be *Clio pyramidata* (from 8 localities) and *Cavolinia longirostris* (from 7 localities).

Included in this report are records of a number of specimens of Euthecosomata from the collections of the Indian Museum, for the loan of which I have to thank Dr. Baini Prashad, Director of the Zoological Survey of India.

The classification of the group here adopted is that of Pelseneer (1888), with the modifications of Meisenheimer (1905) and Tesch (1913).

The following is a list of all the species in the collection :

EUTHECOSOMATA.

LIMACINIDÆ.

Limacina inflata (d'Orbigny).
L. trochiformis (d'Orbigny).

CAVOLINIIDÆ.

Creseis virgula Rang.
Cr. acicula Rang.
Hyalocylis striata (Rang).
Styliola subula (Quoy & Gaimard).
Clio chaptali (Souleyet).
C. pyramidata Linnæus.
C. cuspidata (Bosc).
Diacria trispinosa (Lesueur).
D. quadridentata (Lesueur).
Cavolinia longirostris (Lesueur).
C. globulosa (Rang).
C. tridentata (Forskål).
C. uncinata (Rang).
C. inflexa (Lesueur).

PSEUDOTHECOSOMATA.

CYMBULIIDÆ.

Cymbulia sibogæ Tesch.
C. ? peroni de Blainville.

GYMNOSOMATA.

PNEUMODERMATIDÆ.

Pneumoderma ? pacificum (Dall).

CLIONIDÆ.

Clionina longicaudata (Souleyet).

A. EUTHECOSOMATA.

Family LIMACINIDÆ.

Genus *Limacina* Cuvier.

This genus is represented by two species only and few specimens.

Limacina inflata (d'Orbigny).

Atlanta inflata, d'Orbigny, 1836, p. 174, pl. xv, figs. 16–19.
Spirialis rostralis, Souleyet, 1852, p. 216, pl. xiii, figs. 1–10.
Limacina inflata, Pelseneer, 1888, p. 17.

OCCURRENCE.—Sta. 61 (night), Northern Area of Arabian Sea, surface, 1 specimen.

Limacina trochiformis (d'Orbigny).

Atlanta trochiformis, d'Orbigny, 1836, p. 177, pl. xii, figs. 29–31.
Limacina trochiformis, Pelseneer, 1888, p. 29.

Occurrence.—(i) Sta. 61 (day), Northern Area of Arabian Sea, surface, 2 specimens.
(ii) Sta. 61 (night), Northern Area of Arabian Sea, surface, 2 specimens.
Indian Museum Specimens.—Marine Survey, "Investigator", Sta. 542, off Tavoy I., surface, 1 specimen.

Limacina sp.

Occurrence.—Sta. 136, Maldive Area, surface, 5 specimens.
Remarks.—The shells of these specimens are lost, apparently destroyed by the preservative, thus rendering specific identification uncertain.

Family Cavoliniidæ.

Representatives of six of the seven genera recognized by Meisenheimer are present in the material.

Genus *Creseis* Rang.

The genus is represented by two species.

Creseis virgula Rang.

Creseis virgula, Rang, 1828, p. 316, pl. xvii, fig. 2.
Cleodora virgula, Souleyet, 1852, p. 196, pl. viii, figs. 18–25.
Clio (*Creseis*) *virgula*, Pelseneer, 1888, p. 48.

Occurrence.—(i) Sta. 61 (day), Northern Area of Arabian Sea, surface, 51 specimens.
(ii) Sta. 61 (night), Northern Area of Arabian Sea: (*a*) surface, 35 specimens; (*b*) 1500–0 metres, 1 specimen.
(iii) Sta. 76B, Gulf of Oman: (*a*) 200 metres, 12 specimens; (*b*) 1500 metres, 1 specimen.
(iv) Sta. 96, Central part of Arabian Sea, 400–0 metres, 1 specimen.
Indian Museum Specimens.—(i) S. Point, Port Blair, Andaman I., numerous very small specimens.
(ii) Stewart Sound, N. Andaman I., 2 small specimens.
(iii) Off W. Coast of Strait I., Middle Andaman, 3 small specimens.
(iv) "Investigator" Station off Cape Comorin, 30 fms. (55 metres), 2 specimens.

Creseis acicula Rang.

Creseis acicula, Rang, 1828, p. 318, pl. xvii, fig. 6.
Cleodora acicula, Souleyet, 1852, p. 194, pl. viii, figs. 10–17.
Clio (*Creseis*) *acicula*, Pelseneer, 1888, p. 51.

Occurrence.—(i) Sta. 61 (day), Northern Area of Arabian Sea, surface, 2 specimens.
(ii) Sta. 61 (night), Northern Area of Arabian Sea: (*a*) surface, 40 specimens; (*b*) 1000–0 metres, 2 specimens.

(iii) Sta. 76B, Gulf of Oman, 200 metres, 14 specimens.

(iv) Sta. 95, Central part of Arabian Sea, 984–430 metres, 1 specimen.

(v) Sta. 131D, Southern Area of Arabian Sea, 500–0 metres, 4 specimens.

(vi) Sta. 147, Maldive Area, 27 metres, numerous specimens.

(vii) Sta. 149, Maldive Area, 238 metres, 14 specimens.

INDIAN MUSEUM SPECIMENS.—(i) W. Coast of Strait I., Middle Andaman, 6 small specimens.

(ii) Stewart Sound, N. Andaman, 11 small specimens.

(iii) "Investigator" Station off Cape Comorin, 30 fms. (55 metres), 18 specimens and empty shells.

(iv) Marine Survey, "Investigator", Sta. 461, Bay of Bengal, 375 fathoms (691 metres), 8 shell-less specimens (day).

(v) Marine Survey, "Investigator", Sta. 542, off Tavoy I., surface, 81 large specimens (night).

RECORDED DISTRIBUTION.—The species has been taken on several occasions by the "Valdivia" and Percy Sladen Expeditions in the Indian Ocean between lat. 3° S. and 10° S.; once at the South end of the Maldive Archipelago (Tesch, 1910, p. 166), and North of Cape Gardafui (Meisenheimer, 1905, p. 16).

REMARKS.—Most of the above localities are relatively near to land, but the wide distribution of the new localities indicates that *Cr. acicula* is not confined to inshore or shoal water, but occurs throughout the whole Arabian Sea. Most of the specimens from Sta. 61 (night) are young. The specimens from Stations 147 and 149 were obtained in the grab.

Genus *Hyalocylis* Fol.

Hyalocylis striata (Rang).

Creseis striata, Rang, 1828, p. 315, pl. xv, fig. 7.
Cleodora striata, Souleyet, 1852, p. 191, pl. viii, figs. 1–4.
Clio (*Hyalocylix*) *striata*, Pelseneer, 1888, p. 54, pl. ii, fig. 3.

OCCURRENCE.—(i) Sta. 61 (night), Northern Area of Arabian Sea: (*a*) surface, 45 specimens; (*b*) 1000–0 metres, 8 specimens; (*c*) 1500–0 metres, 4 shell-less specimens.

(ii) Sta. 76B, Gulf of Oman, 200 metres, 5 specimens.

(iii) Sta. 96, Central part of Arabian Sea, 645–400 metres, 25 specimens.

(iv) Sta. 131D, Southern Area of Arabian Sea: (*a*) 500–0 metres, 2 specimens; (*b*) 1500–0 metres, 1 shell-less specimen.

(v) Sta. 186, Gulf of Aden, 250–0 metres, 60 specimens.

INDIAN MUSEUM SPECIMENS.—Marine Survey, "Investigator," Sta. 461, Bay of Bengal, 375 fms. (691 metres), 8 shell-less specimens (day).

REMARKS.—The above records for the species indicate a probable distribution over the whole Arabian Sea; there is, however, still a large area between the equator and 10° N. where, except for a single locality off the Maldives, no specimens have been obtained. The specimens from Sta. 61 (night), surface, are all young.

Genus *Styliola* Lesueur.

Styliola subula (Quoy & Gaimard).

Cleodora subula, Quoy & Gaimard, 1827, p. 233, pl. viii *d*, figs. 1–3.
Styliola subula, Gray, 1850, p. 17.
Clio (*Styliola*) *subula*, Pelseneer, 1888, p. 57.

Occurrence.—Sta. 61 (night), Northern Area of Arabian Sea, 1500–0 metres, 1 specimen.

Recorded Distribution.—In the Indian Ocean the species is most abundant between 25° S. and 34° S., except round the Cape of Good Hope, where it extends considerably farther southwards. Only six localities have been noted—two on the East African Coast, one off Mauritius, one on the Saya de Malha Bank (Tesch, 1910), and two in the Eastern part of the Indian Ocean.

Remarks.—The scarcity of the species in the northern part of the Indian Ocean and the Arabian Sea is in accordance with Meisenheimer's statements (1905, p. 19) regarding its distribution. The distribution of the species on the East African Coast can possibly be attributed to the presence there of cooler Antarctic water flowing up the African coast.

Genus *Clio* (s. str.) Linnæus.

This genus is represented by three species.

Clio chaptali (Souleyet).

Cleodora chaptali, Souleyet, 1852, p. 183, pl. vii, figs. 1–5.
Clio chaptali, Pelseneer, 1888, p. 61, pl. ii, fig. 7.

Occurrence.—(i) Sta. 131D, Southern Area of Arabian Sea, 500–0 metres, 1 specimen.

(ii) Sta. 172, Central part of Arabian Sea, 2091 metres, 1 specimen.

Recorded Distribution.—This species is only known from three previous localities : West of the Cape of Good Hope (Souleyet, 1852), off the East coast of Australia (Pelseneer, 1888), and from between the Canary Islands and Cape Blanco (Meisenheimer, 1905).

Remarks.—The species appears to be widely distributed in tropical and subtropical waters, but nowhere seems to occur in large numbers.

Clio pyramidata Linnæus.

Clio pyramidata, Linnæus, 1767, p. 1094.
Cleodora lanceolata, Souleyet, 1852, p. 179, pl. vi, figs. 17–25.
Clio (*Clio*) *pyramidata*, Pelseneer, 1888, p. 63.

Occurrence.—(i) Sta. 61 (day), Northern Area of Arabian Sea, 500–0 metres, 2 specimens.

(ii) Sta. 61 (night), Northern Area of Arabian Sea : (*a*) surface, 7 shell-less specimens ; (*b*) 1000–0 metres, 6 specimens ; (*c*) 1500–0 metres, 6 shell-less specimens.

(iii) Sta. 95, Central part of Arabian Sea, 984–430 metres, 14 shell-less specimens.

(iv) Sta. 96, Central part of Arabian Sea, 645–400 metres, 1 specimen.

(v) Sta. 98, Central part of Arabian Sea, 2800–0 metres, 1 specimen.

(vi) Sta. 131D, Southern Area of Arabian Sea, 500–0 metres, 2 specimens.

(vii) Sta. 172, Central part of Arabian Sea, 850–0 metres, 2 specimens.

(viii) Sta. 186, Gulf of Aden, 250–0 metres, 1 specimen.

REMARKS.—*Clio pyramidata* is one of the commonest Pteropods in the Arabian Sea ; it is a conspicuous constituent of the Pteropod ooze to be found at the Southern end of the Red Sea and in the Gulf of Aden.

Clio cuspidata (Bosc).

Hyalæa cuspidata, Bosc, 1802, p. 241, pl. ix, figs. 5–7.
Cleodora cuspidata, Souleyet, 1852, p. 176, pl. vi, figs. 11–16.
Clio (*Clio*) *cuspidata*, Pelseneer, 1888, p. 66.

OCCURRENCE.—(i) Sta. 96, Central part of Arabian Sea, 645–400 metres, 3 specimens.

(ii) Sta. 131D, Southern Area of Arabian Sea, 2500–0 metres, 1 shell-less specimen.

(iii) Sta. 172, Central part of Arabian Sea ; (*a*) 400–0 metres, 1 specimen ; (*b*) 850–0 metres, 2 specimens ; (*c*) 2091 metres, 1 specimen.

Genus *Diacria* Gray.

Diacria trispinosa (Lesueur).

Hyalæa trispinosa, Lesueur, 1821, p. 82.
Diacria trispinosa, Gray, 1850, p. 10.
Hyalæa trispinosa, Boas, 1886, p. 94, pl. i, fig. 3, pl. ii, fig. 14.

OCCURRENCE.—Sta. 131D, Southern Area of Arabian Sea, 500–0 metres, 1 specimen.

RECORDED DISTRIBUTION.—Almost all previous records for the species in the Indian Ocean are south of the equator ; there is a single record from the Bay of Bengal. It appears to be abundant south-east of the Cape of Good Hope, but less so further east in the Indian Ocean and decreases in numbers rapidly northwards. The most northerly localities so far recorded are north of the Chagos Archipelago and in the Amirante Group (Tesch, 1910, p. 167) and the " Valdivia " stations 226 and 257, west of Chagos and off the East African Coast respectively (Meisenheimer, 1905, p. 28).

REMARKS.—The species appears to be most abundant in the South-west Indian Ocean and very rare north of the equator in the Arabian Sea. Deposit shells, but no living animals, have been found in the Gulf of Aden, but not elsewhere in the northern Arabian Sea.

Diacria quadridentata (Lesueur).

Hyalæa quadridentata, Lesueur, 1821, p. 81.
Hyalæa quadridentata, Boas, 1886, p. 99, pl. i, fig. 4, pl. ii, fig. 15.
Cleodora pygmæa, Boas, 1886, p. 84, pl. iv, figs. 50, 57, 57 *bis*, pl. v, fig. 90.
Diacria quadridentata, Meisenheimer, 1905, p. 29.

OCCURRENCE.—(i) Sta. 61 (night), Northern Area of Arabian Sea : (*a*) Surface, 2 specimens ; (*b*) 1000–0 metres, 6 specimens ; (*c*) 1500–0 metres, 1 specimen.

(ii) Sta. 96, Central part of Arabian Sea : (*a*) 10 metres, 22 specimens ; (*b*) 645–400 metres, 1 specimen.

(iii) Sta. 131D, Southern Area of Arabian Sea, 500–0 metres, 1 specimen.

(iv) Sta. 172, Central part of Arabian Sea, 800–0 metres, 1 specimen,

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Remarks.—One specimen from Sta. 61, 1000–0 metres, and all those from Sta. 96, 10 metres, are of the young form " *Cleodora pygmæa* " Boas.

Genus *Cavolinia* Abildgaard.

This genus is represented by five of the six known species.

Cavolinia longirostris (Lesueur).

Hyalæa longirostris, Lesueur, 1821, p. 81.
Hyalæa lævigata, d'Orbigny, 1836, p. 110, pl. vii, figs. 15–19.
Hyalæa longirostris, Boas, 1886, p. 102, pl. i, fig. 5, pl. ii, fig. 16.
Cavolinia longirostris, Pelseneer, 1888, p. 79.

Occurrence.—(i) Sta. 61 (night), Northern Area of Arabian Sea : (*a*) Surface, 11 specimens ; (*b*) 1500–0 metres, 1 specimen.

(ii) Sta. 76A, Gulf of Oman, surface, 1 specimen.

(iii) Sta. 76B, Gulf of Oman : (*a*) 200 metres, 10 specimens ; (*b*) 2500 metres, 3 specimens.

(iv) Sta. 94, Central part of Arabian Sea, 1045–984 metres, 1 specimen.

(v) Sta. 95, Central part of Arabian Sea, 984–430 metres, 16 specimens.

(vi) Sta. 96, Central part of Arabian Sea : (*a*) 10 metres, 9 specimens ; (*b*) 645–400 metres, 13 specimens.

(vii) Sta. 131D, Southern Area of Arabian Sea, 500–0 metres, 16 specimens.

(viii) Sta. 172, Central part of Arabian Sea : (*a*) 200–0 metres, 23 specimens ; (*b*) 400–0 metres, 28 specimens ; (*c*) 850–0 metres, 59 specimens ; (*d*) 2091–0 metres, 245 specimens.

(ix) Sta. 186, Gulf of Aden, 2500–0 metres, 1 specimen.

Indian Museum Specimens.—(i) Marine Survey, " Investigator ", Sta. 542, off Tavoy I., surface, 119 specimens.

(ii) Marine Survey, Sta. 556, off Tavoy I., surface, 7 specimens.

(iii) " Investigator ", North Point Andaman I., surface, 9 specimens.

(iv) " Investigator ", off Moscos I., 29 small specimens.

Remarks.—Two specimens from Sta. 96, 10 metres, and one from Sta. 131D, are of the young form " *Hyalæa lævigata* " d'Orbigny.

Cavolinia globulosa Rang.

Cavolinia globulosa, Rang, 1850, p. 8.
Hyalæa globulosa, Boas, 1886, p. 107, pl. i, fig. 7, pl. ii, fig. 18.
Cavolinia globulosa, Pelseneer, 1888, p. 81.

Occurrence.—(i) Sta. 96, Central part of Arabian Sea, 645–400 metres, 6 specimens.

(ii) Sta. 131D, Southern Area of Arabian Sea, 2500–0 metres, 2 specimens.

(iii) Sta. 172, Central part of Arabian Sea : (*a*) 200–0 metres, 2 specimens ; (*b*) 400–0 metres, 2 specimens.

Indian Museum Specimens.—(i) Marine Survey, " Investigator ", Sta. 461, Bay of Bengal, 375 fms. (691 metres), 1 specimen.

(ii) Mita, Tavoy, Burma, 4 specimens.

Remarks.—The species is common in the Bay of Bengal and eastern part of the Indian Ocean, and probably occurs almost as frequently in at least the central and southern parts of the Arabian Sea. At present it is unknown from the northern part and the Gulf of Oman.

Cavolinia tridentata (Forskal).

Anomia tridentata, Forskål, 1773, p. 124.
Hyalæa complanata, Gegenbaur, 1855, p. 40.
Hyalæa tridentata, Boas, 1886, p. 115, pl. i, figs. 8, 9, pl. ii, fig. 19, pl. iv, fig. 66, pl. vi, fig. 100.
Cavolinia tridentata, Pelseneer, 1888, p. 83.

Occurrence.—(i) Sta. 131D, Southern Area of Arabian Sea, 500–0 metres, 1 specimen.

Remarks.—The species seems to be more abundant in the southern and eastern portions of the Indian Ocean. North of the equator the species is practically unknown except for occasional remains in the bottom deposits. These remains are more common on the African coast. Meisenheimer says of *C. tridentata*: "... häufig ist sie (dann weiter) im ganzen indischen Ocean, wo ihre Sudgrenze ... auf 40° S. Br. liegt ..." His chart, however (Karte vi), of the distribution of the species scarcely bears out this statement, for he gives 25 localities south of Lat. 25° S. and only 5 north of this line. The failure of the expedition to capture *C. tridentata* north of the equator would seem to indicate that the Arabian Sea lies rather outside the zone of distribution of this species and that it occurs only sparsely here, though if the dead shells may be taken as a guide, it is more abundant on the western side of the sea.

The species has never been taken alive in the northern and central parts of the Arabian Sea, though occasional deposit shells are found in the Gulf of Aden. From its scarcity, where known, in the area it is not unlikely that it may be absent from the northern part of the Arabian Sea and the Gulf of Oman.

The single specimen obtained belongs to the young form "*Hyalæa complanata*" Gegenbaur (1855, p. 40).

Cavolinia uncinata (Rang).

Hyalæa uncinata, Rang, 1836, p. 93, pl. v, figs. 11–15.
Hyalæa uncinata, Boas, 1886, p. 119, pl. i, fig. 10, pl. ii, fig. 20.
Cavolinia uncinata, Gray, 1850, p. 7.

Occurrence.—(i) Sta. 95, Central part of Arabian Sea, 984–430 metres, 1 specimen.

(ii) Sta. 96, Central part of Arabian Sea: (*a*) 10 metres, 2 specimens; (*b*) 645–400 metres, 7 specimens.

Indian Museum Specimens.—(i) "Investigator", Northern part of Andaman Sea, surface, 16 specimens.

(ii) Marine Survey, "Investigator", Sta. 274, Laccadive Sea, 1170–1150 fms. (2160–2123 metres), 1 specimen.

Cavolinia inflexa (Lesueur).

Hyalæa inflexa, Lesueur, 1813, p. 285, pl. v, fig. 3.
Hyalæa inflexa, Boas, 1886, p. 123, pl. i, fig. 11, pl. ii, fig. 21, pl. vi, figs. 98 *a–l*.
Cavolinia inflexa, Pelseneer, 1888, p. 85.

Occurrence.—Sta. 96, Central part of Arabian Sea, 10 metres, 1 specimen.

Recorded Distribution.—Except for a single record in the Bay of Bengal all previous records for the species in the Indian Ocean are from south of the equator.

Remarks.—This single specimen has the shell completely decalcified by the preservative, but is quite intact and distinctly of the typical form of *C. inflexa*.

b. PSEUDOTHECOSOMATA.

Family Cymbuliidæ.

Genus *Cymbulia*.

The genus is represented by one species and fragments of what may be a second species.

Cymbulia sibogæ Tesch.

Cymbulia sibogæ, Tesch, 1904, p. 54, pl. iii, figs. 88–90.

Occurrence.—(i) Sta. 7, Red Sea, 260 metres, 237 specimens, 2633 empty shells.
(ii) Sta. 131d, Southern Area of Arabian Sea, 2500–0 metres, 2 specimens.

Recorded Distribution.—Specimens are known from the East Indies (Tesch, 1904, p. 54), Gulf of Guinea, North of Cocos I., South of Ceylon, Chagos Archipelago, Seychelles, South-east of Cape Gardafui (Meisenheimer, 1905, p. 38).

Young specimens, probably of this species but without the deutoconch, are recorded from the following additional areas : Amirante Group, Gulf of Aden (Meisenheimer, 1905, p. 38), Mauritius, Providence and Farquhar Atolls (Tesch, 1910, p. 168).

Remarks.—The collection from Sta. 7 consists almost entirely of shells ; there are only 237 animals, all separated from the shell. Only 85 of these animals have the " tail " well developed on the ventral fin, the others being tailless. All the shells appear to be those of young animals varying in size from 11·0 mm. to 22·0 mm. The largest specimens are thus slightly smaller than the largest collected by the " Siboga ". Meisenheimer (*loc. cit.*), however, records very much larger specimens averaging 30·0 mm. in length, some being 39·0 mm. long—more than half as long again as the type-specimens, the largest of which only measured 24·0 mm. in length.

The specimens from Sta. 131 are 2 shells and 2 shell-less animals, but as they are the only animals of this type from this station it is highly probable that shells and animals belong to one another.

All the tests differ from the type in having a much more acute dorsal end and the rows of spines on the aboral surface somewhat sinuous. In the type these latter are said to be straight. The specimens, however, are not referable to either the large or small types of *C. peroni* de Blainville on account of the acute dorsal end, the small equal spines and the rows of spines running to the ventral point being sinuous and not simply curved.

Cymbulia sp.

Occurrence.—(i) Sta. 18, Gulf of Aden, 900–0 metres, 2 specimens.

(ii) Sta. 61 (night), Northern Area of Arabian Sea: (*a*) 1000–0 metres, 2 small specimens; (*b*) 1500–0 metres, 1 small specimen.

(iii) Sta. 131D, Southern Area of Arabian Sea: (*a*) 500–0 metres, 5 specimens; (*b*) 1500–0 metres, 12 specimens.

(iv) Sta. 170, Central part of Arabian Sea, 3676 metres, 1 large damaged specimen.

(v) Sta. 172, Central part of Arabian Sea, 200–0 metres, 7 specimens.

Remarks.—These specimens all resemble *C. sibogæ*, but as all have lost the deutoconch it is impossible to identify them with certainty.

If these shell-less specimens are included it would seem that the species is common in the southern half of the Arabian Sea and at least present in the northern half of the area. Moreover it penetrates into the Red Sea, as is evident from the large haul of specimens at Sta. 7, though probably it does not extend very far northwards in this area.

Cymbulia ? peroni de Blainville.

Cymbulia peroni, de Blainville, 1818, p. 333, pl. lix, fig. *a*.

Occurrence.—Sta. 7, Red Sea, 260 metres, fragments.

Remarks.—These fragments appear to belong to a number of specimens of some large species of *Cymbulia*. Some of them are covered with small denticles similar to those which form a large patch on the aboral surface of *C. peroni*, but it is not possible to be sure that they belong to this species.

c. GYMNOSOMATA.

The Gymnosomata are represented by two genera belonging to different families.

Family Pneumodermatidæ.

Genus *Pneumoderma* Cuvier.

This genus is represented by two specimens belonging to one species.

Pneumoderma ? pacificum (Dall).

Pneumodermon pacificum, Dall, 1871, p. 139.
Pneumonoderma pacificum, Pelseneer, 1887, p. 30, pl. ii, figs. 4, 5.
Pneumoderma pacificum, Meisenheimer, 1905, p. 50.

Occurrence.—Sta. 61 (night), Northern Area of Arabian Sea, surface, 2 specimens.

Recorded Distribution.—This species was first recorded by Dall from the West coast of North A erica, since when it has been taken several times in the North Pacific

between latitudes 30° N. and 40° N., and as far north as 58° N. (Alaska) on the eastern side of the Pacific. It has not previously been obtained outside the Pacific.

Remarks.—The specimens are only indifferently preserved and are considerably contracted, but they appear to conform most nearly to the descriptions of this species.

Family Clionidæ.

The various species of gymnosomatous Pteropoda referable to the family Clionidæ have had a somewhat chequered history. The early history of the family is summarized by Pelseneer (1887), who adopted the name *Clione* Pallas for those Gymnosomata hitherto described under the name *Clio*, which name he transferred on grounds of priority to a series of thecosomatous species. Pelseneer reduced the number of reasonably well-defined species, identifiable from the literature, to three, namely *Clione limacina*, *Cl. longicaudata* and *Cl. flavescens*. He rejected the suggestion put forward by Macdonald (1864, p. 187) that the species should be generically separated on the number of pairs of buccal cones into those with three and those with two pairs.

By 1923 three new genera, *Paraclione* (Tesch, 1904), *Pædoclione* (Danforth, 1908) and *Cephalobrachia* (Bonnevie, 1914), had been added to the Clionidæ and the number of accepted species of *Clione* had increased to seven, namely :

Clione limacina, *Cl. longicaudata*, *Cl. flavescens* } Pelseneer, 1887.
Cl. punctata Tesch, 1904.
Cl. gracilis Massy, 1907.
Cl. antarctica E. A. Smith, 1902.
Cl. kincaidi Agersborg, 1923.

Pruvot-Fol (1924) investigated in detail the anatomy of the head-region in *Cl. longicaudata*, and found constant differences between this species and *Cl. limacina* in the structure of the radula, buccal cones, hook-sacs and penis. On the basis of these facts she subdivided *Clione* into two genera, *Clione* s. str. including *C. limacina* (Phipps) and other species with six buccal cones, and *Clionina* for *Cl. longicaudata* and possibly *Cl. flavescens* which have four buccal cones.

The single specimen in the collection belongs to the genus *Clionina*.

Genus *Clionina* Pruvot-Fol.

Clionina longicaudata (Souleyet).

Spongiobranchia elongata, d'Orbigny, 1840, p. 132, pl. ix, figs. 8, 9.
Clione caudata, Gray, 1850, p. 37.
Clio longicaudatus, Souleyet, 1852, p. 286, pl. xiv, figs. 17–21.
Clionina longicaudata, Pruvot-Fol, 1924, p. 364, pl. xv, figs. 15–17, text-figs. 14–17.

Occurrence.—Sta. 61 (night), Northern Area of Arabian Sea, surface, 1 specimen.

Recorded Distribution.—This species has been frequently recorded from the Atlantic by the " Challenger ", " Valdivia " and the Plankton-expedition within a belt extending from 4° N. to 36° N. and extending to nearly 40° N. in the Gulf Stream. It has been recorded several times from the Eastern Mediterranean (Kwietniewski, 1902 ; Lo Bianco, 1903 ; Pruvot-Fol, 1924). It has not previously been taken in the Indian Ocean.

THE VERTICAL DISTRIBUTION OF THE PTEROPODA.

Oberwimmer (1898, p. 573), working on material from the Mediterranean and considering all the species of Pteropoda and Heteropoda together, found that the maximum number of individuals was obtained at the surface between 18.45 and 20.45 hrs., and that from then on less were caught—apparently as a result of the downward migration of the animals. A second, though smaller, surface maximum occurred between 3.45 and 5.30 hrs., *i. e.* at dawn. By day few or no specimens were caught at the surface. Thus the double diurnal rhythm is more or less universal within these two groups of animals, though it is highly probable that different species vary in their time of actual maximum surface concentration according to their sensitivity to light

In the following paragraphs only those species are mentioned for which there are several records in the present collection and of which a fair number of specimens are available.

In dividing the present records into " night " and " day " stations for constructing the distribution diagrams, the hours from 6.00 to 18.00 have been regarded as day, this period corresponding approximately to the duration of daylight in the Arabian Sea. The diagrams give only an approximate illustration of the range of distribution, owing to the small number of specimens captured at almost all depths save that at which the maximum concentration occurs. Hence the lower parts of the figures are for the most part doubtful, *e. g.* Text-fig. 1, C and F, where only a few specimens were obtained from the greater depths.

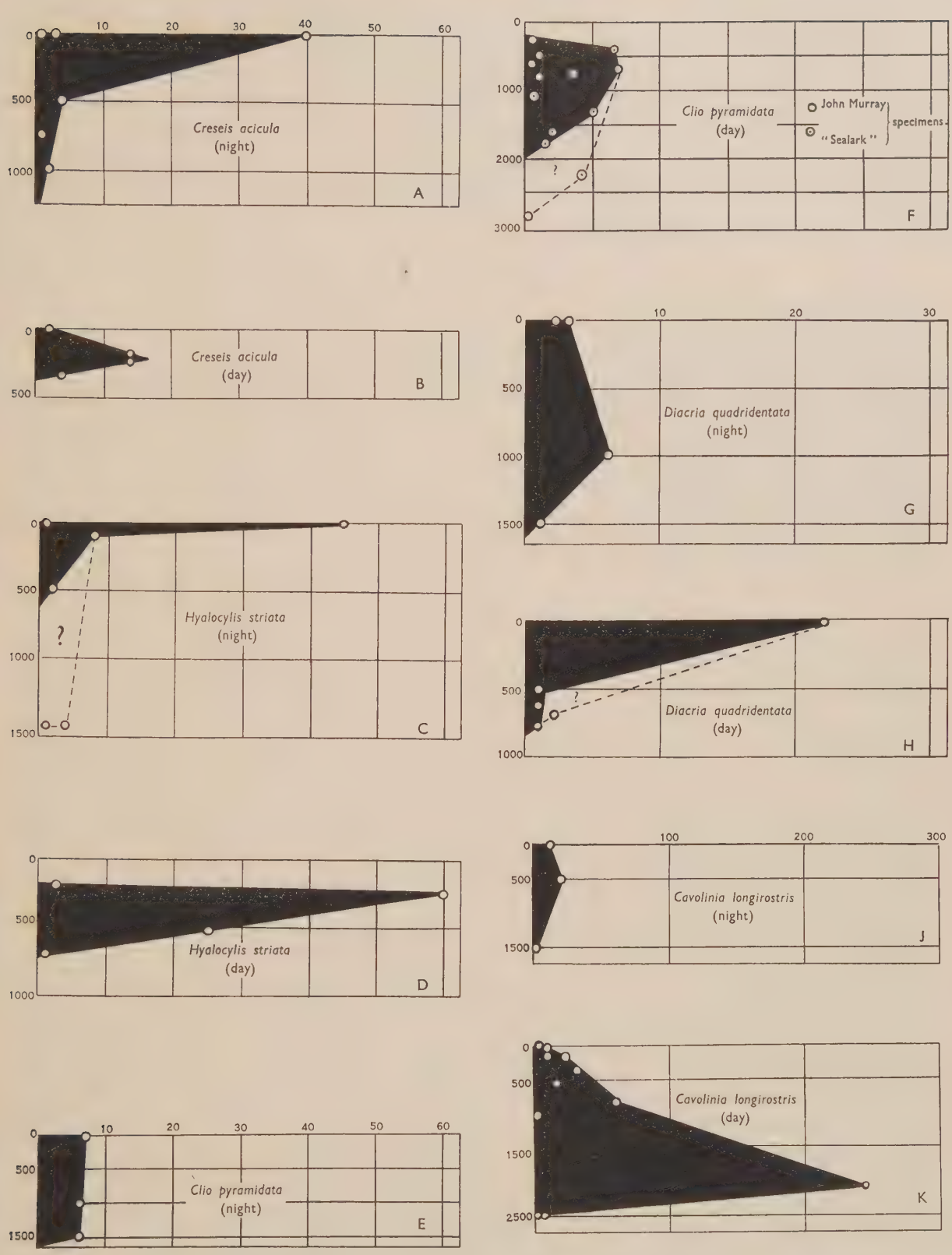
Creseis virgula.

Fryer (1869, p. 269) has stated that *Cr. virgula* occurs at the surface throughout the 24 hours. The present records, though not extending over a whole day, indicate a surface maximum in the afternoon (*c.* 13.00–14.00 hrs.). The record from Sta. 61 (night), 1.30 hrs., shows a high concentration of the species at the surface, apparently indicating a second surface maximum concentration in the early hours, and thus a double diurnal migration towards the surface. If this is so it would appear that the vertical migration of *Cr. virgula* is not controlled by light-intensity, but by some other stimulus such as the need for food or the physical conditions in the water. It is unfortunate that there is only one record, and that of a single specimen, for the period 2.00–12.00 hrs., as such a record would probably establish whether the species remains at the surface or descends, to rise again in the afternoon.

The species evidently inhabits the upper 200 metres, but the records are insufficient to indicate how much deeper it may go.

Creseis acicula (Text-fig. 1 A, B).

Creseis acicula seems to appear at the surface in numbers at night only. The present records indicate only a comparatively short vertical range of about 500 metres, with a daylight concentration at about 250 metres. Fryer (1869, p. 269) lists this species also as occurring at the surface throughout the 24 hours. Only a few, however, appear to remain in the upper strata during the period of intense illumination. It is interesting to note that at the shallow-water stations 147 and 149 in Horsburgh Atoll this species was



TEXT-FIG. 1.—Vertical distribution by day and night of the more abundant species: A, B, *Creseis acicula*; C, D, *Hyalocylis striata*; E, F, *Clio pyramidata*; G, H, *Diacria quadridentata*; J, K, *Cavolinia longirostris*.

abundant, and had evidently migrated right to the bottom in considerable numbers and thus was brought up by the grab. Sewell (1935, p. 526) has recorded the great abundance of *Clio* sp. (probably this species or *Cr. virgula*) in the shallow water of an atoll. He says: " On one occasion over a litre and a half of a species of Pteropod, *Clio* sp., were taken in a surface townet . . . that was left awash at the surface for a period of twelve hours." *Cr. acicula*, like *Cr. virgula*, must be able to withstand a comparatively high light-intensity as it occurs in very shallow water, *e. g.* 28 metres at Sta. 147, where even at the bottom the illumination must still be strong.

Hyalocylis striata (Text-fig. 1 C, D).

This species appears to frequent a depth between 200 and 500 metres by day, but quite obviously rises to the surface at night (Text-fig. 1 C). It is possible that the specimens obtained from 1500 metres were caught during the hauling of the net and so belong to a much higher level, as it is not likely that the animals would both ascend and descend from the day position under the same set of conditions. This species also is listed by Fryer (1869, p. 269) as occurring at the surface by day and night, again probably due to its capability of withstanding a fairly high light-intensity, and so descending later and to a less depth than other and more sensitive species.

Clio pyramidata (Text-fig. 1 E, F).

The daylight distribution of this species appears to lie below 250 metres, with a maximum concentration somewhere between 430 and 984 metres. The " Sealark " Expedition obtained a maximum concentration of this species at about 369 metres, so 400–500 metres is probably near the level occupied by *Clio pyramidata* by day. Ignoring the single specimen from 2800–0 metres, probably caught as the net was hauled, the indicated lower limit for the present collection is about 900 metres. The " Sealark " obtained specimens from considerably greater depths, indicating a possible range to about 2000 metres or more, though this is unlikely. Lo Bianco also (1903, pp. 142 *et seq.*) obtained specimens from the Mediterranean at a depth of 1900 metres with both closed and open nets, and also from 2600 metres with an open net. The latter specimens were young, and may have been caught by the net on its way to the surface. Young individuals are not confined to very deep water, as the same author records them from 900, 1100 and 1200 metres. Hence the species probably has a vertical range of about 2000 metres.

The night distribution is clearly shown by the records from Sta. 61 (Text-fig. 1 E). Almost equal numbers were collected from 0, 1000 and 1500 metres, indicating that all the individuals do not rise to the surface, but that there is a general upward movement of the animals, filling up the surface layers. Owing to the great distance to the surface the stimulus drawing them upwards is probably removed before the bulk of the animals reach the surface, and they then become evenly distributed in the upper 1500 metres. Thus only those lying nearest the surface by day will reach it at night. Russell (1925, p. 791 ; 1926, p. 432) has shown that this is probably so for *Calanus finmarchicus* and the medusa *Cosmetira pilosella*. This distribution is what might be expected from a consideration of the daytime distribution of *Clio pyramidata*, as it is scarcely conceivable that these animals could migrate through 2000 metres or more each night.

This species also has occasionally been recorded at the surface during daylight. The large vertical range with its attendant change of temperature is in full agreement with Bonnevie's view (1914, p. 51) that this is an eurythermal species.

Clio cuspidata.

The few available records point to a daytime range from about 400–900 metres with a maximum concentration at about 500 metres. No specimens were obtained in the night plankton hauls.

Diacria quadridentata (Text-fig. 1 G, H).

Fryer (1869, p. 269) records this species from the surface during daylight. This is to some extent confirmed by the present records. The night hauls indicate a possible concentration at 1000 metres, but 8 hours later a distinct maximum is found at 10 metres, *i. e.* at the surface. Unfortunately there are no records for the rest of the day. The " Sealark " Expedition, however, found specimens at 738 metres at noon (Tesch, 1910, pp. 167, 171), so there is a possibility that *D. quadridentata* descends again during the period of highest illumination, in which case it probably reappears at the surface at twilight, thus having a double diurnal migration like *Cr. virgula*. *D. quadridentata* would seem to prefer the less intensive illumination to be found at dawn and twilight. Owing to this crepuscular habit the diagrams (Text-fig. 1 G, H) tend to give a slightly distorted impression, as no distinction is made between full daylight and the weak light of dawn and evening. The surface daylight distribution (Text-fig. 1 H) is not a permanent daytime position, but only occurs in the early hours (the actual maximum charted occurred at 9.10 hrs.) and perhaps again in the evening.

Cavolinia longirostris (Text-fig. 1 J, K).

There appears to be a considerable concentration of this species at about 2000 metres by day (Text-fig. 1 K). At night, apparently, the animals may be distributed more or less evenly throughout the top 800 metres (Text-fig. 1 J), perhaps rather more densely at 500 metres, below which level they become less frequent. A considerable number seem to occur at this depth throughout the 24 hours. It is not possible from the present results to determine when the greatest frequency at the surface occurs. There is, however, a large concentration of animals at 2000 metres in the afternoon which indicates that they are heliophobic and hence probably only rise to the surface at night. Bonnevie (1914, p. 51) classes this species as a surface-living, stenothermal form, as the " Michael Sars " only obtained it in the Atlantic from above 250 metres and mainly at the surface. The present records clearly indicate that *C. longirostris* is a distinctly eurythermal species. At Sta. 172 it was taken in water of temperature ranging from about 15° to 3·5° C.

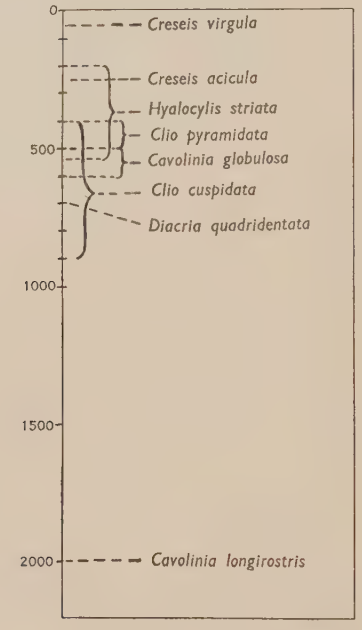
Cavolinia globulosa.

The present records indicate a daytime distribution at about 500–600 metres for this species. The " Sealark " records (Tesch, 1910, pp. 169–171) indicate a much lower level, namely, at about 1400 metres. As, however, only a few specimens were obtained by either expedition, it is difficult to determine at what level the animals lie during the day.

The most specimens (10) were obtained from 1400 metres (Tesch, 1910, p. 171). There is only a single record for a night haul, and so it is impossible to determine at what time the species is at the surface.

GENERAL REMARKS ON VERTICAL DISTRIBUTION.

The different depths at which the various species of Pteropods occur during the day and the different times at which they appear at the surface—at night, dawn, early morning, etc.—indicate that the different species probably prefer different light-intensities. Presumably this preference determines their distribution in depth. Text-fig. 2 shows



Text-fig 2.—Vertical distribution of various species by day.

the depths at which the species discussed above occur by day. Oberwimmer (1898, p. 573), as mentioned above, obtained an average time of appearance at the surface which showed that the majority were crepuscular animals appearing at the surface at dawn and in the evening. Still earlier, Fryer (1869, p. 269) classified the Pteropoda to be met with in the South Atlantic and Indian Ocean as night, day or crepuscular animals. He concluded that many species were present at the surface at all times. This was probably due to the longer period spent at the surface by some species compared with others. Meisenheimer (1905, p. 98) came to the conclusion that the Eu- and Pseudothecosomata must be regarded as coming to the surface at night (" Nachttiere ") and the Gymnosomata by day (" Tagtiere ").

The problem does not, however, admit of such a simple settlement. It seems fairly clear that some species prefer a higher or lower light intensity than others and hence appear at the surface at different times. Moreover they will descend to a greater or less depth depending on whether the day is brilliant or dull, and also on whether the water is

clear, thus admitting of greater light penetration, or is cloudy. It is more than probable that the suggestion put forward by Michael (1911, pp. 133, 144) for *Sagitta bipunctata*—that the animal lives at an optimum light intensity—is applicable to the movements of the Pteropoda. At sundown this species follows this optimum surface-wards, but after dark the stimulus to ascend is removed and the animals sink back probably to the water layers offering the best combination of other factors, such as temperature and perhaps salinity. With the coming of dawn the animals rise to meet the optimum and follow it downwards. Hence the second appearance at the surface and the double diurnal rhythm as indicated for *Cr. virgula* and *D. quadridentata* and perhaps other species. Those species preferring a very low light intensity will rise very near to the surface at night, whereas those liking a high intensity will lose the stimulus earlier and so begin to sink back earlier in the night. At dawn the reverse process will occur, those liking a low intensity preceding the others at the surface. As the intensity increases during the morning the last to leave the surface will be forms such as *Cr. virgula* and *Cr. acicula*, which prefer a fairly high light intensity and consequently never sink to a very great depth. For instance, the present materials indicate that *Cr. acicula* has a maximum daylight concentration at only about 250 metres, whereas other species sink to 1000 or even 2000 metres (*Cavolinia longirostris*). Michael (1911, p. 145) has pointed out that "*. . . a few almost always remain in deeper water during twilight, and on the surface during intense light and darkness*". This statement is made for the species of *Sagitta*, but apparently it applies equally to some of the Pteropoda, such as *Creseis* spp., and this would account for the statements of some observers that these forms are surface-living during daylight.

It is of interest to note that those species that were found in any numbers at Sta. 76 in 200 metres, namely *Creseis virgula*, *Cr. acicula*, *Hyalocylis striata* and *Cavolinia longirostris*, were also found to be common at the surface at Sta. 61 either by day or night or both (*Cr. virgula*). Apparently the conditions here are equally suitable for all four species, though *C. longirostris* is also found at considerable depths, whereas the other species are usually to be found in the upper 500 metres. One other species, *Clio pyramidata*, was fairly common at Sta. 61 at the surface, but also occurred here in about the same numbers at 1000 and 1500 metres, and so was not confined to the particular water mass inhabited by the preceding four species. This species did not occur at Sta. 76. These four species were not found in as large numbers at other depths at these stations though elsewhere they occurred at much greater depths, *e. g. C. longirostris* was very common at 2000 metres at Sta. 172 in water of Polar origin. Hence the particular conditions at these two stations are apparently not essential for this latter species, though they may offer the optimum conditions in these localities. The following data for these two positions are of interest :

Station.	Time.	Depth (m.).	Temperature (° C.).	Salinity.	Number of specimens.
76	15.30	200	17·48	36·24	14
61 (night)	1.26	0	27·83	36·27	40

It is thus seen that the animals were here living at different depths (the depth being probably dependent upon the time of day) and under very different conditions of temperature. The animals at Sta. 76 have doubtless descended because of the high light intensity

of the afternoon, whereas at Sta. 61 in the dark they are at the surface. Apparently the stimulus of light is stronger than that of temperature, as otherwise the animals would hardly move through water with such a large range of temperature.

It is interesting to see that these two bodies of water have very nearly the same salinity. This suggests that the particular depth assumed by day by these four species may be to some extent linked with the salinity, the particular depth taken up being that in which the light intensity is not too great and the salinity is somewhere about 36·25, regardless of the temperature of the water. Unfortunately the records from other stations do not support this suggestion. At Sta. 172, to take one example, specimens were found at varying depths to 2091 metres, and the salinity varied considerably from 35·50 at 200 metres to 34·88 at 2000 metres, all the values being considerably below that quoted above. Hence as far as the present records go, there is no indication that salinity has any great effect upon the distribution of the Pteropoda.

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